PROJECT MANAGEMENT

I. Introduction

One of the most important steps that can be taken in effectively managing a project is to establish, up front, a plan for completing the project. During the 1950's two techniques for managing projects were developed. The Program Evaluation and Review Technique (PERT) was developed by the Navy as a means to better manage the R&D efforts that led to the production of the Polaris missile system. At about the same time the Critical Path Method (CPM) was developed by the duPont Company to aid in the management of plant maintenance and construction projects. Over time these two techniques have coalesced and have become known as network analysis. There are three components that make up a network analysis, the Work Breakdown Schedule, the PERT Chart, and the Gantt Chart. These three things together give the program manager an effective tool for understanding the scope of a project, as well as, understanding the time line for the project.

II. Work Breakdown Schedule

The Work Breakdown Schedule (WBS) is a pictorial representation of the tasks that must be accomplished in order to complete the project. The WBS is a tiered structure. The top level represents the project as a whole and each successive level down represents a major subdivision of the project, until at the bottom level the individual tasks that must be completed are identified. This hierarchy type structure facilitates identification of all the tasks that are to done, but also helps to define responsibility and lines of communication for the individuals overseeing specific tasks. As an illustration of this consider the design of an all terrain vehicle for which the WBS is shown in figure 1. At the top level is the design as a whole, the next level down contains the breakdown of the design into fabrication, installation and testing, and the final level in this example relates to the specific components. The WBS contains no information about the order in which the tasks must be completed, or the time period over which the project will be completed. However, it does answer the question what needs to be done. Completing the WBS before the project gets under way reduces the risk of overlooking important aspects of the project.

III. Pert Chart

The next aspect of the project to be addressed is the order in which the individual tasks are to be completed. The PERT Chart or network diagram establishes the relationships between the various tasks. This is accomplished by setting up a precedence table that shows which tasks must precede other tasks. Once the table is completed, this data is illustrated on the PERT Chart. Table 1 lists all of the tasks for the ATV Design and establishes the order in which they must be completed. Figure 2 is the corresponding PERT Chart or network diagram for the project. Note that there are tasks that run in parallel as well as tasks that run in series. The PERT Chart helps identify how personnel and resources must be allocated in order to keep the project progressing. The question of how long the project will take still has not been answered, but the progression of the project is now clear.

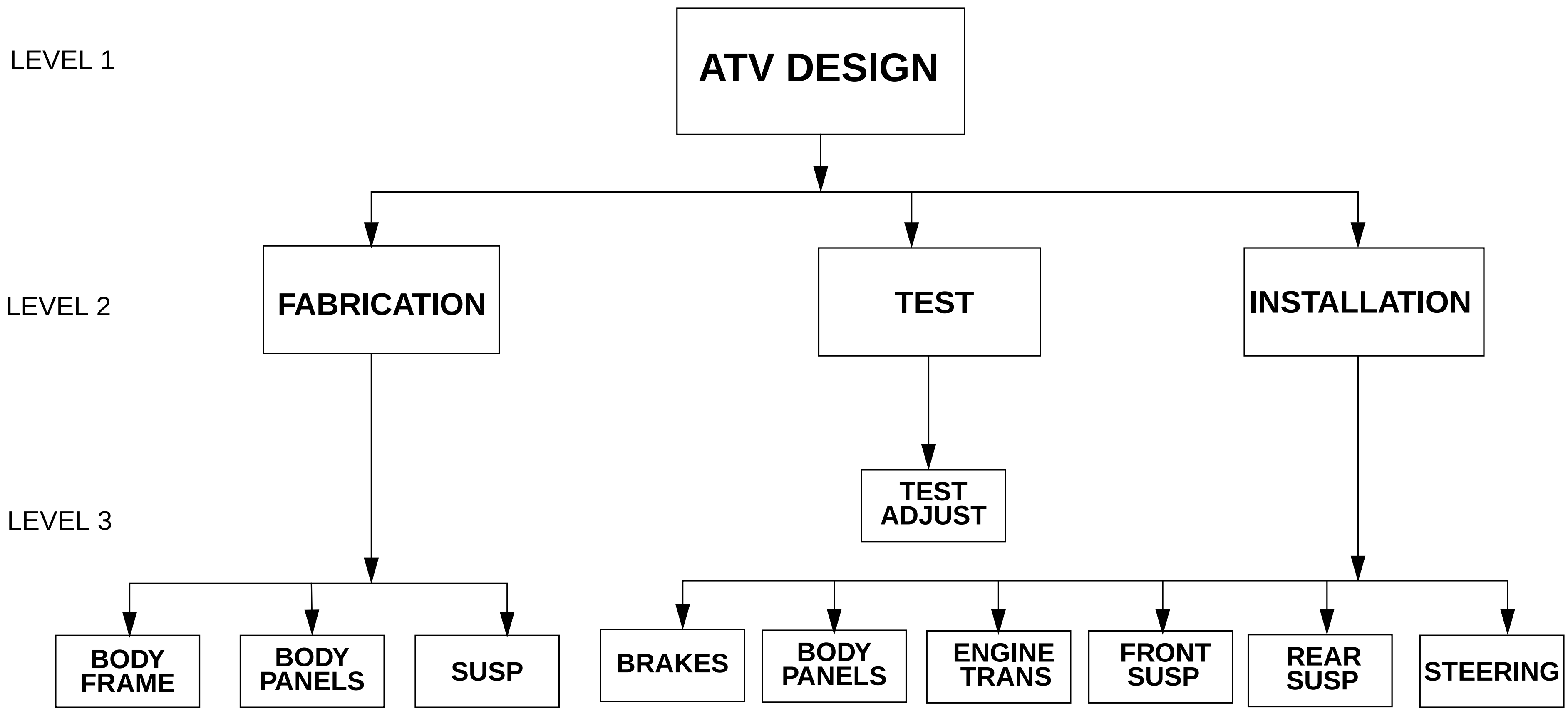

Figure 1 ATV DESIGN WORK BREAKDOWN SCHEDULE

Table 1: ATV Design Task Precedence

ACTIVITY	DESCRIPTION	PRECEEDING ACTIVITIES	DURATION (days)
A	Fabricate Body Frame		10
B	Fabricate Body Outer panels		6
C	Install Body Outer Panels	B, K	1
D	Install Engine/Transmission	A	4
E	Fabricate Suspension		6
F	Install Front Suspension	A, E	4
G	Install Rear Suspension	A, E	2
H	Install Steering	F	4
J	Install Brakes	G, H	4
K	Test and Adjust	D, J	5

IV. Gantt Chart

The final piece of information that is needed to effectively manage the project is a time line showing how long the project will take and when the specific tasks will start and finish. The Gantt Chart provides this information, drawing on the precedence data established by the PERT Chart and the expected durations of each of the tasks. The Gantt Chart for the ATV Design is shown in figure 3. The cross hatched bars on the chart show the Critical Path for the project, which is the longest path from the start to the finish through the PERT Chart. This is the maximum amount of time that it will take to complete the project.

V. Critical Path and Slack Time Determination

As stated above, the Critical Path is the maximum amount of time that will be required to complete the project. It is determined by finding all the different paths of activities that lead from the start of the project to the finish, the longest path is the Critical Path. Referring to the ATV Design Pert Chart there are six possible paths from the start to the finish, these are listed in table 2. Path 4 in table 2 has a total duration of 28 days which is the longest path, and therefore the Critical Path. The other paths through the project take less time. As a result the activities on these paths could “slip” some in scheduling without delaying the finish date of the overall project. This “slip” is referred to as slack (S) and it can be determined for each activity in the network. In calculating the slack time for each activity there are four other parameters that are used. They are Latest Start Time (LS), Latest Finish Time (LF), Earliest Start Time

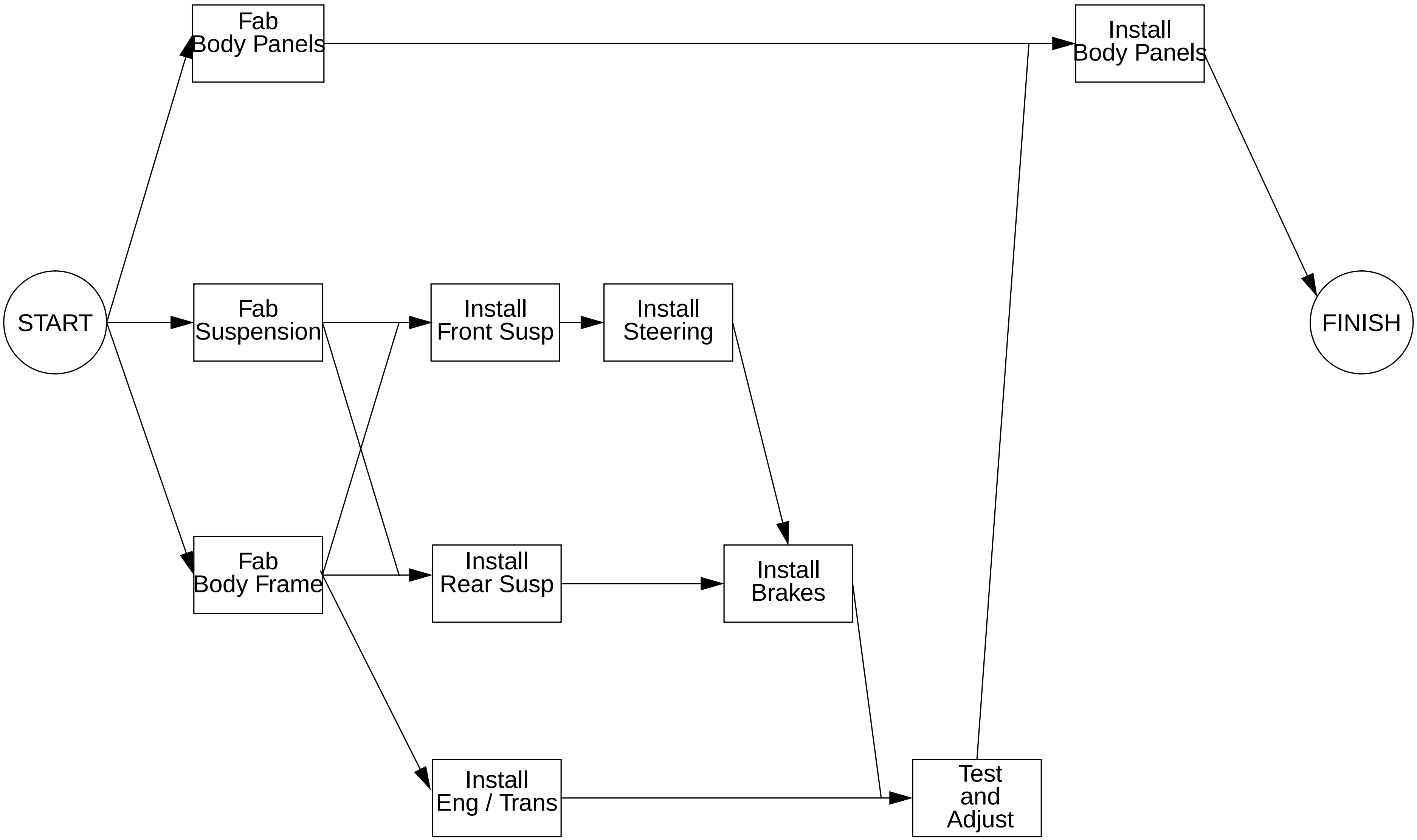

Figure 2 ATV DESIGN PERT CHART

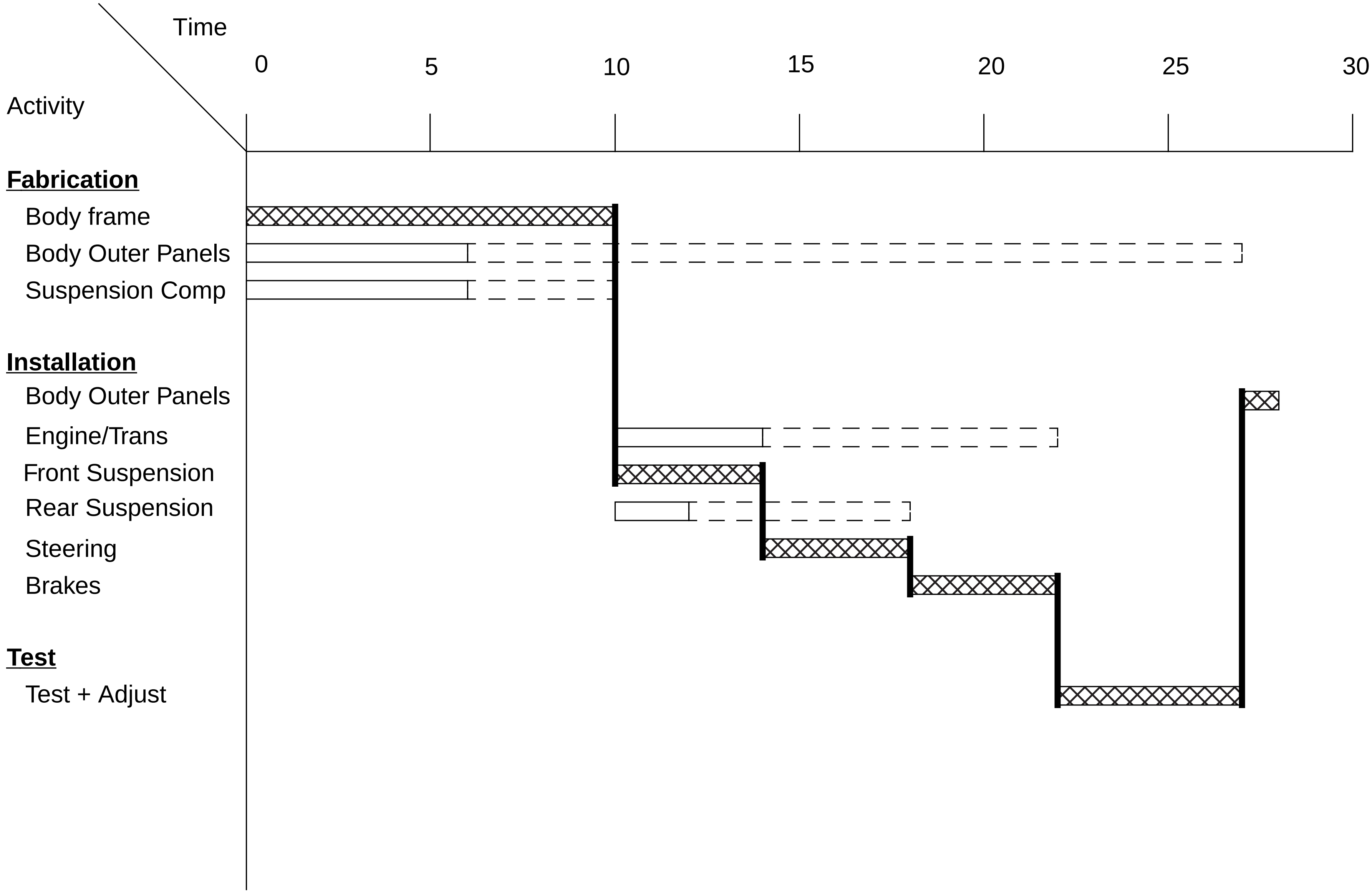

Figure 3 ATV DESIGN GANTT CHART

Table 2: ATV Design Critical Path

Path	Activities	Duration (days)
1	B, C	7
2	E, F, H, J, K, C	24
3	E, G, J, K, C	18
4	A, F, H, J, K, C	28
5	A, G, J, K, C	22
6	A, D, K, C	20

(ES) and Earliest Finish Time (EF). These quantities are calculated for each activity in the network. The definitions of these times are:

LS - the latest time at which an activity can begin without delaying the completion time of the project. This is determined by taking the difference between the Critical Path time and the sum of durations for this activity and the longest path of activities that succeeds this activity.

LF - the latest time at which an activity can be completed without delaying the completion of the project. This is the sum of the latest start time for the activity and its duration.

ES - the earliest time at which an activity can begin. This is determined by summing the durations for the longest path of activities preceding the current activity.

EF - the earliest time at which an activity can be completed. This is the sum of the earliest start time and the duration for the activity.

Having determined the quantities above, the slack for each activity is determined by taking the difference between the latest finish time and the earliest finish time or taking the difference between the latest start time and the earliest start time:

$$S = LS - ES \quad \text{or} \quad S = LF - EF \ . \qquad (1)$$

<u>EXAMPLE:</u> Determine the slack for activity G, install rear suspension, in the ATV Design.

In order to calculate the slack the quantities LS, LF, ES, and EF will be determined. Looking at activity G there are two paths of preceding activities, and one path of succeeding activities. The succeeding activities are J, K, and C, which have a total duration of 10 days. This coupled with the duration of activity G makes the total duration for this activity and the longest path of activities succeeding it 12. The LS becomes 16, which is the difference between this value and the critical path time of 28. The LF is 18, the sum of the LS and the duration for activity G. The two paths of activities preceding G are A and E. The duration of activity A is 10 days and the duration of activity E is 6 days. Therefore, the ES for activity G is 10 days, determined by activity A. The EF becomes 12 days, the sum of ES and the duration of activity G. Based on these values for LS, LF, ES, and EF the slack for activity G is 6 days, the difference between LF and EF or LS and ES. This means that the start, finish, or duration of activity G could be delayed by up to 6 days without impacting the finish time for the project. If a delay of greater than 6 days is encountered then the project finish date will be delayed and the critical path will change to include activity G.

Table 3 provides the LS, LF, ES, EF, and S for all of the activities in the ATV Design.

Table 3: ATV Design Slack

Activity	LS	LF	ES	EF	S
A	0	10	0	10	0
B	21	27	0	6	21
C	27	28	27	28	0
D	18	22	10	14	8
E	4	10	0	6	4
F	10	14	10	14	0
G	16	18	10	12	6
H	14	18	14	18	0
J	18	22	18	22	0
K	22	27	22	27	0

It should be noted that the slack time for any activity on the critical path is zero.

VI. Estimation of Activity Duration

There are two methods for establishing the duration of an activity. The deterministic approach uses a single value for the duration, which is based on actual experience in performing the activity over and over. This is the measure of time that was used by duPont in developing the CPM. The types of activities that were encountered in the building and maintenance of plants were well understood and documented, so assigning a single value for the duration was not difficult.

The probabilistic approach uses a weighted average of three times to establish the duration for an activity. This approach is used when there is not a great deal of experience or confidence in estimating the duration of an activity. This approach was used in developing the PERT method. Recall that PERT was developed by the Navy to manage the Polaris missile project, which was largely an R&D effort. Many of the activities associated with the project were new, and as a result there was not much experience to draw on in estimating durations. The three measures used were:

Most Pessimistic Time (MP) - there would only be a 1% chance of taking longer than this amount of time, this would correspond to everything going wrong.

Most Likely Time (ML) - this represents the time required if the activity was performed over and over by experienced personnel.

Most Optimistic Time (MO) - there would only be a 1% chance of taking less than this amount of time, this would correspond to everything going right.

These three separate measures are combined to provide an estimate of the duration for the activity:

$$D = \frac{MP + 4ML + MO}{6} . \tag{2}$$

Using this probabilistic approach an estimate of the uncertainty in the duration of an individual activity or a sequence of activities can be made. For an individual activity the uncertainty is:

$$\sigma_i = \frac{MP - MO}{6} , \tag{3}$$

where the difference in MP and MO represents a $\pm 3\sigma$ limit on the most likely time. Now, for a sequence of activities the uncertainty in the total duration is:

$$\sigma_T = \sqrt{\Sigma \sigma_i^2} . \tag{4}$$

Therefore, a small σ_i or σ_T would indicate a low uncertainty in the estimate of the duration, which would give the project manager a high level of confidence that the activity or sequence of activities could be completed in the allotted time. Conversely, a large σ_i or σ_T would indicate a high uncertainty in the estimate, which would give the project manager cause for concern.